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ABSTRACT

Both the development and evaluation of one of a set of computer programs designed for use by visitors as adjuncts to museum exhibits are described. Museum displays used were (1) a static, behind-glass exhibit on evolution; (2) a hands-on primitive stone age tools exhibit; and (3) a Foucault pendulum. A computer placed next to each exhibit served as a simulation of a teacher who asked questions by way of a video screen and received responses keyed in on a typewriter keyboard. Questions about the visitors were used in the analysis of responses to leading questions to cue the computer response to the sophistication and age of the user. A preliminary study for the evolution program showed that the mean scores for a 4-question test, administered via computer to 138 randomly selected visitors over the age of 14, were significantly higher for the visitors who had used the computer program for that exhibit than for those who had used one of the other programs. This report also describes the design and results of an experiment to test the effectiveness of one section of the program, and outlines some practical conclusions drawn from project experiences. (MER)

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CRANBROOK INSTITUTE OF SCIENCE

EXHIBITS ENHANCED BY STAND-ALONE COMPUTERS

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ABSTRACT

This is a report on a project dedicated to developing the use of computers as adjuncts to exhibits in museums. Included are both the development and the evaluation of one of the three computer programs being used as bridges between visitors and three exhibits at Cranbrook Institute of Science. This phase (May 1979 - February 1981) was funded by The Michigan Council for the Humanities, among others, equipment donated by the Apple Education Foundation. The approach used was to place a computer next to an exhibit, as a simulation of a teacher at that exhibit. This teacher "speaks" by way of a video screen and hears through a typewriter keyboard. The computer asks for, and later uses, the visitor's name and age. It asks leading questions, accepts and analyzes prose inputs, responding according to the sophistication and age of the visitor.

The museum displays used for this project were: (1) a static, behind-glass exhibit on evolution, (2) a hands-on primitive stone age tools exhibit and (3) a Foucault pendulum. The evolution exhibit contains replicas of pre-human, human and ape (hominoids) fossil skulls; the tools, replicas of three early tools. The Foucault pendulum consists of a large brass ball swinging from the ceiling, and a small model mounted on a turn table. Each exhibit is accompanied by its own computer and computer program.

The computers have been a great success in the museum. Visitors can be seen clustered around them at all times (when there are people in the museum). They interact with the computers, with the exhibits, and with each other. A preliminary study for the evolution program showed that the mean scores for a four question test were significantly higher for the computer-program users than for those not aided by computer.

INTRODUCTION

Computers are now in use in many museums. Typically they catalogue and cross-reference collections or, at the interactive level, play games with visitors (tic-tac-toe and the like), or ask non-exhibit related multiple-choice questions. At Cranbrook Institute of Science we have tried a different approach, placing a computer next to an exhibit to teach about that exhibit. This teacher "speaks" by way of a video screen and "hears" through a typewriter keyboard.

A great deal of effort is expended in designing museum exhibits and labels, but without help visitor learning is inadequate. Understandably, it is difficult to learn about unfamiliar materials in a noisy and distracting museum hall. The computer has the affect of focusing visitor attention by asking questions and giving feedback after a visitor response. A properly designed computer program can, using a Socratic questioning technique, help the user consider a sequence of ideas, leading to an understanding of information contained in an exhibit. The three computers ask for, and later use, the visitor's name and age. They ask leading questions, accept and analyze prose inputs, responding according to the sophistication and age of the visitor. The following is a description of the three exhibits and associated programmed teaching sequences used in this project. The Foucault pendulum and evolution exhibit already existed, the tools exhibit was developed for the computer project.

The evolution exhibit (see figures 1, 2 and 3) contains reproductions of fossil skulls of early human and ape ancestors,

fig. 1
The evolution exhibit. The clay reconstructions and artifacts can be seen next to the fossil skulls

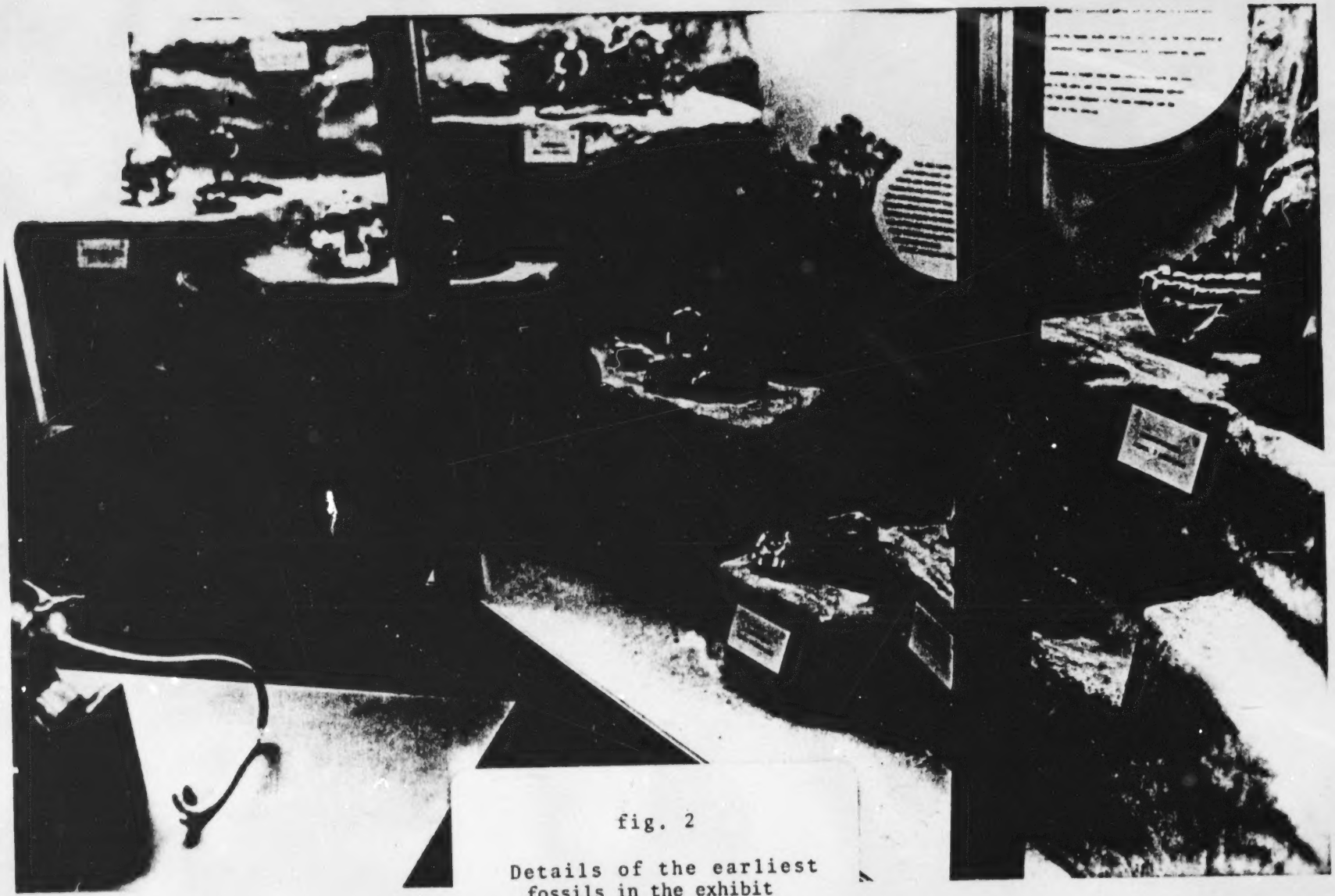


fig. 2

Details of the earliest fossils in the exhibit
The child is looking at dryopithecus

fig. 3

The computer and the
plaster ape and human skulls

as well as of present-day apes. The skulls are displayed on rock-like shelves with small clay reconstructions of the whole creature next to them. The small creatures are shown engaged in probably daily activities such as digging for food, making a fire or whatever is an appropriate activity for their stage of development. Actual stone tools found with the hominids are also displayed on the shelves. Together the clay reconstructions and the artifacts help to illustrate the development, both physical and cultural, of the hominids at various stages. The microcomputer and two full-size plastic skulls--one a modern human, the other a modern orangutan--are next to the behind-glass exhibit on specially designed tables.

As the dialogue begins, the computer asks the visitor to observe differences between the skulls of a modern ape, a modern human, and a recent common ancestor of both. It proceeds to explore the degrees of difference and some of the environmental and cultural reasons for these differences between the ape and the human evolutionary lines of descent. Through the evolution program, museum visitors are hopefully made aware of themselves as members of a species with a unique history not only of physical development but cultural development as well.

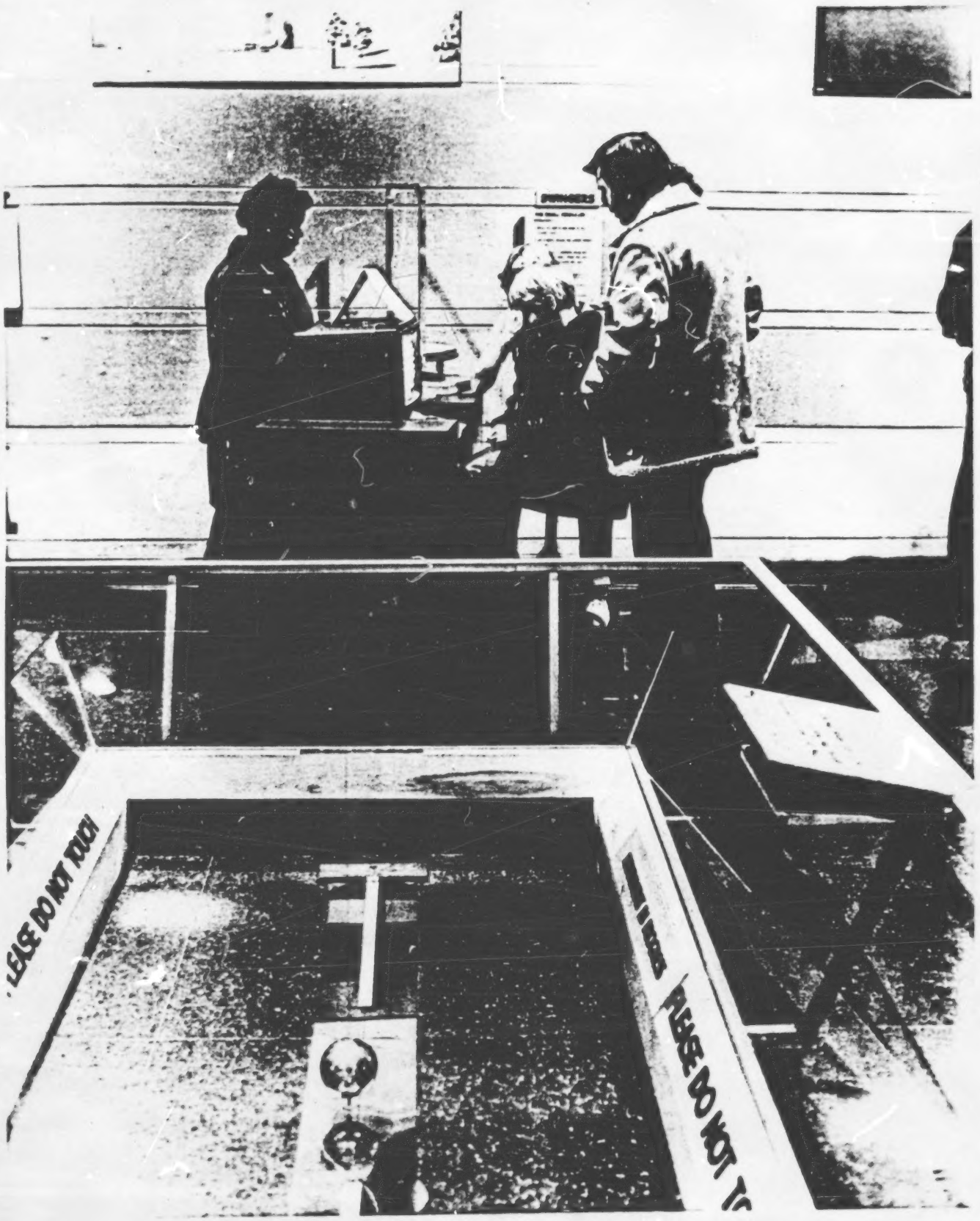
The adaptive ability of humans to reason or plan ahead is directly related to the second exhibit which explores the making of stone tools; including a pebble tool, an Acheulian hand axe, and a European spear point approximately 30,000 years old (See figure 4). The dialogue encourages museum visitors to examine and touch these tools as well as to find their own answers to the question: "What makes us human?" Degrees of complexity in workmanship are explored. Finally, the visitor is asked to consider the implications of increasing complexity--was the brain that produced the Acheulian hand-axe as highly developed as your brain? How about the spear point? Even the computer itself, an advanced tool, is worked into the dialogue.

The Foucault pendulum (See figure 5) is actually two exhibits; a ten-pound brass ball hanging by a 22 foot piano wire from the ceiling, and a smaller model hanging from a support attached to a one foot diameter turntable. The computer is located on a console and placed between the two. The computer instructs visitors to read the label and experiment with the small pendulum, establishing that the direction of the ball's swing does not change when the supporting turntable is turned. This concept is generalized to be true for the large pendulum as well, and the question is raised: "Why isn't the large ball still swinging along the line?" The subsequent dialogue leads to the inference that the line, therefore the floor, and therefore the earth are doing the turning.

Using computer programs coordinated with static exhibits offers some unique advantages. Without active involvement, either physical or mental, visitors cannot, and do not, concentrate

fig. 4

The Tools Exhibit
and Computer


PLEASE DO NOT TOUCH
PLEASE DO NOT

their attention on any exhibit long enough to consider the content in detail, let alone the implications of the content. In fact, it has been documented that in most museums, visitors spend only an average of 45 seconds at any one exhibit. Using an inquiry technique similar to that of a Socratic teacher, the computers guide participants through a series of questions and answers, causing visitors to reflect, interact and hypothesize. The time spent by many visitors at computer enhanced exhibits has increased by a considerable amount.

While the computer might be thought to limit usage to one person at a time, in fact small groups often cluster around to discuss what they feel are suitable answers. The answer finally typed is sometimes a composite of several people's ideas. The great success of the computer programs probably stems from the fact that people come to museums for social as well as educational reasons. With the computer as a focus, people freely discuss the question posed, not only with their own group, but with others whom they have never met before.

The rest of this report will:

. describe the development of the evolution program as an example

. describe the evaluation conducted simultaneously with the above development

. describe the design and results of an experiment to test the effectiveness of one section of the evolution program

. outline some practical conclusions that we have drawn from our experiences.

THE EVOLUTION PROGRAM: AN EXAMPLE

INITIAL DEVELOPMENT

Before work on the evolution program was begun, a microcomputer had already proved successful with the Foucault pendulum, a hands-on exhibit in Cranbrook's interactive Physics Hall. How difficult would it be to start from scratch with a "behind-glass" exhibit? Could people's understanding of a static, natural-history exhibit be improved by an inquiry-style dialogue with a microcomputer? Happily, the answer is "yes."

We began by asking ourselves what we wanted to teach about evolution; what concepts were important. We then decided to focus on characteristics that were easy to observe and explain, such as the size of the cranium. A look at Figure 2 (p.3) shows that the exhibit was not adequate for this purpose.

The youngster is looking at the upper jaw of our earliest fossil, a dryopithecine, . . . no cranium there! To the right of the child's head are a few teeth from a ramapithecine,. . . no cranium there! But look, there's a cranium for Homo erectus in the upper middle of the picture, but only the cranium, the rest of the skull is missing. The existing exhibit did not illustrate clearly the evolution of the cranium. This experience occurred over and over in our attempts to develop the program. Much of the needed material was lacking in the exhibit (as it often is in real life when dealing with fossils). Our conclusion--rather than asking what <u>we</u> wanted to teach about evolution, we needed to ask "What does the <u>exhibit</u> teach about evolution?"

FINAL DESIGN

"What does the exhibit have to say?" The designer of a learning sequence must examine the exhibit and outline exactly what is to be taught at that exhibit, always making sure that the information is there! At this point some additions to or deletions from the exhibit may be necessary. In our case we placed a plastic human and orangutan skull next to the computer to enable visitors to more easily make the comparison between the two. Our first broad teaching outline went as follows:

1. Introduction to computer and how to use it.
2. Introduction to the exhibit and observation of differences between ape and human skulls.
3. Environmental differences which led to some of the observed differences between apes and humans.
4. More extensive comparison of physical changes in the hominids only.
5. Specific comparisons of A. Robustus, H. Habilis and A. Africanus (thought to have lived at the same time).
6. More extensive comparison of the modern human and orangutan skulls.
7. Ending.

The above outline then must be broken down further. For example:

1. Introduction to computer
   A. Use of RETURN key
   B. How to correct mistakes.

This process of outlining the conversation must continue down to the actual dialogue level. To make this complicated

procedure managable, each branch must be considered as a complete unit, and programmed as a subroutine in the computer program. Each must be small enough for the programmer to understand and keep the logic obvious. (Computer specialists call this "structured programming.")

We decided not to modify the keyboard, thus giving our visitors "real-world" experience with an actual keyboard. However, the computers must be modified to prevent the user from gaining access to the actual program, preventing computer buffs from practicing their art on the computers. The computer program must be foolproof and prepared for any input. If a "yes" or "no" is the desired answer, any other response must be met with "Please type yes or no." If the computer does not find any key words, it must reply "I don't understand," and rephrase the question. The visitor must never be left in doubt about what to do!

Often the initial attraction is the computer, not the exhibit. Attention must immediately be drawn to the exhibit by asking questions about the key elements. Without these frequent references, the computer might become and remain the prime focus of interest. For example, in step 2 of the above instructional sequence, the visitor is asked to locate first Homo sapiens and then Dryopithecus in the exhibit and is later questioned about the differences between ape and human skulls. The program will not proceed without correct responses to observational questions about the exhibits. Visitors can be seen responding to these three computer requests in Figures 1, 2 and 3 resp.

In the near-final version of the computer program, all

visitors proceeded through steps 1 and 2 of the instructional sequence and were then free to choose any one or all of steps 3-7. However, some people were spending as much as 45 minutes at the computer, forcing us to limit the amount of time--a gratifying change from the usual 40-50 second "flyby" of the original exhibit!

EVALUATION

The evaluation for the computer program should start even before the work is begun. "Who is your audience?" "How old are they?" are a few of the questions that must be answered. This process is described quite thoroughly by Dr. C.G. Screven of the University of Wisconsin-Milwaukee*. We decided that our audience included everyone 12 years and older. This audience was expected to know nothing about evolution or about computers. Younger children were also expected, but they were going to need the help of adults.

Once the computer has been initially programmed and installed in conjunction with the exhibit, three modes of evaluation are used simultaneously: (1) watching and listening to visitor reactions when using the computer; (2) review of visitor's prose answers to key answers to key questions (stored in the computer memory); and (3) analysis of answers to diagnostic multiple-choice questions asked at critical points in the program (again with answers stored in memory.)

(1) Watching and Listening

By watching we determined that our audience composition was as we had expected it to be. But, many parents let their very

*Screven, C.G., "Exhibit evaluation - a goal-referenced approach," Curator, 19/4, 1976, pp 271-290

young children play unsupervised with the computer (probably because the parents are afraid of the computer). A large sign was then posted at the computer to tell parents they would have to help children who could not read. Now many parents can be seen interacting with computer, exhibit and children.

Many users were confused, and could be seen focusing on the wrong exhibit, or the wrong part of the evolution exhibit. This required frequent references in the program to elements of the exhibit and use of multiple-choice questions asked, to find out what they were looking at. For example, the computer asked the visitor to look at Dryopithecus on the lowest shelf of the exhibit. Unfortunately, they were as likely to look at the wrong fossils as the correct one. More about this problem later.

Listening was important! One visitor was heard talking about "hominio" instead of "hominid". The upper case "D" and "O" look very similar on the display and were confusing people. This problem was solved by writing unfamiliar words containing "O" and "D" in the lower case. Many people were quite vocal as they dialogued with the computer. When the logic was not clear to them, they spoke out about their confusion. (They probably would not speak up so readily to a real teacher.)

(2) Review of Answers

The visitors age and prose answers to key questions were stored in the computer's memory and reviewed later. (See Table I for some conversations.) In this way the appropriateness of the computer responses could be evaluated, greatly improving the dialogue. The development of the following dialogue is one good

example. The computer first told the visitor that Dryopithecus (ancestor to both ape and human) had lived in the forest, and then asked where pongids (the line that led to apes) had lived. We were expecting "forest" or "grasslands" (the two places mentioned in the label). Some answers were: "caves" or "deserts" or "mountains," etc. (one even suggested New York!) The anthropologist then had to outline how the computer should respond in each of the above cases.

When the visitor typed in "caves," for example, the computer was to respond:

PONGIDS DON'T USE CAVES FOR SHELTER. WHERE DO THEY LIVE--GRASSLAND OR FOREST?

In the above interchange the respondent was asked this question after having read the exhibit label. Approximately half of the people reading the label did not understand it. This difficulty may necessitate changing the label, or living with the problem.

TABLE I

A few of the computer conversations about the ape and human skulls

Cyndi, tell me in a few words one difference between the ape and human skulls on the table.

Cyndi: "Apes" teeth are bigger."
Computer: "Well done! We call the long sharp teeth, canine teeth. Humans sometimes have sharp (but not long) canines. Feel your own. It's the third from the middle of your mouth. Is it sharper than your other teeth?"

or

Cyndi: "Jaw is thrust forward."
Computer: "Are you talking about the ape or the human?"
Cyndi: "The ape."

or

Cyndi: "The ape could not smoke a cigarette."
Computer: "I'm sorry, I didn't understand you. Please try again."
Cyndi: "The ape has a jutting jaw."

(3) Diagnostic Multiple-choice Questions

Some visitors had been seen looking at the wrong fossil when asked to consider Dryopithecus (as mentioned on page 14). The following question was inserted at the end of the teaching sequence to find out how many people were making that mistake:

Which of the following might have been your ancestor?

a. pliopithecus

b. gigantopithecus

c. pan

d. dryopithecus

Many people did not choose Dryopithecus, the ancestor suggested by the exhibit, showing that the above was a common problem. To make sure that people were looking at the right component of the exhibit, a multiple-choice question about the small figure next to the fossil was embedded in the teaching sequence. A mistaken identification could then be discovered and immediately corrected.

FINAL EVALUATION OF THE EVOLUTION PROGRAM

DESIGN OF EXPERIMENT

The original plan was to make the final evaluation on a computer (not the evolution computer) under controlled conditions. This required a staff person to randomly choose the subjects to be tested, and police the testing. To keep the statistical variations within satisfactory limits, it was also decided to test only people over 14 years of age. Unfortunately, many users of the evolution program are under 14, and many spent a great deal of time at the computer, so that little data could be collected during even a three hour stint. The lack of staff and time forced a change in the experiment design.

It was decided to tack the evolution test to the end of another exhibit-based computer program in the Physics Hall (the Foucault pendulum). This test was then given to alternate users, over 14, who had finished the Foucault pendulum program. No staff member was present during the testing, except now and then to get a sampling of visitor behavior. Most visitors took the test seriously, so we proceeded to collect data for six consecutive week-ends.

During these six week-ends, 138 adults (over 14) were given this four question multiple-choice test about evolution, each question involving the choice of one correct answer out of four. (See test in Table II). The testing was done entirely by computer, the subject being users of the Foucault pendulum computer in the Physics Hall. This use of only the computer eliminated the possibility of bias arising from a staff person choosing "suitable" people to interview. It also controlled for the difference between computer-users and noncomputer-users; all subjects were computer-users. The evolution exhibit and its computer are in another hall of the museum so those being tested could not see the exhibit. The test was given to alternate people using the Foucault pendulum computer to lessen the probability of subjects taking the test twice. Only people completing the Foucault pendulum program were tested, eliminating "non-serious" users. To ensure that testing was carried out under normal museum conditions the test was used only on week-ends.

After completing the Foucault pendulum computer program, subjects were first asked the following question (p.19):

TEST

I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT OUR EXHIBIT ON EVOLUTION. I WANT YOUR ANSWERS EVEN THOUGH YOU HAVEN"T SEEN THE EXHIBIT. THE ANSWERS OF THOSE WHO HAVE AND HAVE NOT USED THE COMPUTERS WILL BE COMPARED.

DO YOU KNOW ANYTHING ABOUT EVOLUTION?

1. WHICH OF THE FOLLOWING IS YOUR ANCESTOR?

   A. A PONGID
   B. A HOMINID
   C. AN APE
   D. A GORILLA

2. WHICH OF THE FOLLOWING MIGHT HAVE BEEN YOUR ANCESTOR?

   A. PLIOPITHECUS
   B. GIGANTOPITHECUS
   C. PAN
   D. DRYOPITHECUS

3. THE GREAT APES ARE NOT:
   ***

   A. PONGIDS
   B. HOMINIDS
   C. ANTHROPOIDS
   D. PRIMATES

4. WHICH OF THE FOLLOWING MIGHT HAVE BEEN AN APE'S ANCESTOR?

   A. DRYOPITHECUS
   B. AFRICANUS
   C. ROBUSTUS
   D. GORILLA

TABLE II THE CRITERION TEST USED TO EVALUATE THE EVOLUTION COMPUTER PROGRAM.

I'M TRYING TO EVALUATE THE USE OF COMPUTERS IN MUSEUMS.
PLEASE HELP BY ANSWERING A FEW QUESTIONS.
TODAY DID YOU USE, OR WATCH, (IN THE HALL OF MAN):

A. THE COMPUTER WITH THE SKULLS.

B. THE COMPUTER WITH THE STONE TOOLS.

C. BOTH 'SKULLS' AND 'TOOLS' COMPUTERS.

D. NO COMPUTER.

TYPE A, B, C OR D PLEASE.

At this stage the test only contained questions about the beginning sections of the evolution computer program, so the comparison of interest was between individuals selecting A or C and B or D. However, so few people selected "B" that their answers were ignored.

RESULTS

A mean score based on one point per correct answer out of four was calculated for each subject category for each week-end. The overall mean score was 1.7 for A, C which was significantly higher ($p < 0.05$) than the mean score of 1.0 for D.

Study of the incorrect answers revealed that whereas 57% of the subjects who had not used the evolution computer thought that the correct answer to "Which of the following is your ancestor?" was "an ape," only 25% of the subjects who had used it thought so. The answers to the second question were randomly distributed, implying that our visitors were not remembering this unfamiliar technical name (*Dryopithecus*). This kind of information is probably unsuitable in an informal learning environment. An earlier question asking the visitor to classify a picture of A.

robustus as "hominid" or "pongid" had been discarded for similar reasons. The computer and visitor had discussed this classification at the exhibit, but either the picture used in the test was not good enough, or this material was also unsuitable.

SUMMARY

Many of the visitors using the evolution computer did learn information about the exhibit. This evaluation method, using a dedicated computer in another room, provided an unbiased and relatively easy way to sample the particular population in which we are interested: "museum visitors willing to spend some time using a computer." Not only did the computer choose people in a completely random way, but it also saved the results of the test in its memory, and printed them out all neatly at the end. It could also be programmed to perform the statistical analysis and print the results in tabular form.

There will obviously be some inaccuracies; for example, subjects may misclassify themselves as A, B, C or D but the effect of these can be minimized by taking sufficiently large samples.

One obscure distinction between the two population sets is that one of them did not use the evolution computer program. This may have been because they were not interested in the Hall of Man, and did not enter it. Perhaps they did enter the Hall, but the computer was in use, or they may have visited it after the Physics Hall. Only the first reason could have a significant affect on the statistical results, but we assume for now that this effect is negligible. More detailed verification needs a specific study.

CONCLUSIONS

Computers do make an effective bridge between visitor and exhibit. People can be seen interacting in a thoughtful manner with both exhibit and computer, even in a busy and noisy museum hall. During the two years of research on computer-aided exhibits in museums, we have also drawn the following practical conclusions:

1. NOT TOO MUCH WRITTEN MATERIAL should appear on the television screen at one time! The lines of print should be separated by at least one blank line. If possible, the screen should be organized into two or three blocks, each separated by two or three blank lines. The print should scroll slowly, the speed determined by the age of the user.

2. DON'T JUST USE THE COMPUTER AS A BOOK. The computer serves as a bridge between the visitor and the exhibit. Ask a question, or direct attention to something in the exhibit or have the user do something, all requiring some action. The ability of the computer to respond to visitor inputs is the key to its success. The program should invite active participation.

3. THE SEQUENTIAL FLOW OF IDEAS IN A PROGRAM SHOULD BE LOGICAL AND CONSISTENT. Each sentence and idea must flow from the preceding one, especially when the user cannot back up and reread previous material. This became quite obvious while watching people use the computer. As mentioned before, visitors were quite vocal about any confusion.

4. MAKE THE PROGRAM VARIABLE IN LENGTH. Some people would like to spend forty-five minutes, others only five.

These are just a few practices that our experience has taught

us. The computer program can be as long, and as responsive as the developers want it to be. But, to simplify the development of the program, it should be broken up into modules, and evaluated and improved one section at a time. First develop the entire program in beginning form. Then focus on one section, then another, using all the evaluative tools available. Months worth of data can be saved for all parts of the program, but it is important to change just one variable at a time, measure the effect, and then - if necessary - change it again. After all sections have been completed, the entire program should be evaluated as a whole.

This may seem like much trouble, but the big flaws in a program show up almost immediately and can be quickly corrected. Meanwhile, visitors are pleased, even with a flawed program. Watching small clusters of people gathered around the computer and discussing some point about the exhibit makes the "debugging" effort worthwhile!